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Irrigated Acres: A Profile Comparison of 1976-80 and 1981-85

John Hanchar
Kris Barney
Clifford Dickason
William Crosswhite

IRRIGATED ACRES: A PROFILE COMPARISON OF 1976-80 AND 1981-85. By John Hanchar, Kris Barney, Clifford Dickason, William Crosswhite. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1736.

ABSTRACT

U.S. farmers irrigated about the same average number of acres during 1981-85 as in 1976-80. By using the multivariate statistical technique profile analysis, the authors compared average irrigated acreage for the two periods by region and commodity at the national level and by commodity at the State level. The authors had anticipated a decline in the acreage because of lower commodity prices and higher production costs. Irrigated acreage increased in States that irrigated relatively little before and in some principal irrigation States, and decreased in three principal irrigation States in the Southwest.

Keywords: Irrigated acreage, profile analysis, multivariate procedure

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SUMMARY

U.S. farmers irrigated about the same average number of acres during 1981-85 as in 1976-80, despite the drop in commodity prices and the rise in production costs. This report compares average irrigated acreage for the two periods by region and commodity at the national level and by commodity at the State level. The authors used the multivariate statistical technique profile analysis to test the equality of mean vectors of the two periods.

The national analysis, which showed little difference between the periods, actually masked changes that occurred within States. Average irrigated acreage during 1981-85 declined from 1976-80 in heavily irrigated Arizona, Oklahoma, and Texas. Stagnant world markets for the States' farm products and increased production costs including greater real prices of energy forced the States' irrigators to reexamine the level of resource use. Because irrigators had to pump water from greater depths at a high cost, they stopped irrigating some acreage.

Irrigation increased in some States where normal rainfall is enough to support most crops. In the humid States, ground water is generally closer to the surface and available to increase yields at less pumping cost than in the drier States. For example, such humid States as Georgia, Missouri, Illinois, Indiana, Iowa, and the Carolinas experienced increases in irrigated acreage across commodities.

In States that showed little change in irrigated acreage, such as Colorado, Idaho, Utah, and Wyoming, rights to water supplies tended to be regulated through existing legal institutions and past decisions. So, commodity prices and production costs may have had less effect because of such institutional impediments as long-term contractual agreements and water-use laws.

Irrigated Acres: A Profile Comparison of 1976-80 and 1981-85

John Hanchar
Kris Barney
Clifford Dickason
William Crosswhite*

INTRODUCTION

During the 1970's, a period of relative prosperity on the farm, agricultural expansion, and increased irrigation, farmers responded to rising commodity prices and low real interest rates by increasing output. However, declining commodity prices and rising factor costs, for example higher real energy prices and rising real interest rates, have dominated the 1980's.

The purpose of this study is to examine the manner in which irrigated acreage changed in response to the changing economic conditions of 1976-80 and 1981-85. The objectives of this paper are: 1) to test the hypothesis that, at the national level, average irrigated acreage for 1981-85 was the same as average irrigated acreage for 1976-80, by region and commodity, and 2) to test the hypothesis that, at the State level, average irrigated acreage in 1981-85 was the same by commodity as average irrigated acreage in 1976-80. Average irrigated acreage for either period, by region or commodity group, is referred to throughout the paper as a regional or commodity profile of irrigated acreage. Because of the disparity in economic conditions of the two time periods, changes in the regional and/or commodity composition of irrigated acreage at the national level were expected. Changes in the commodity profile of irrigated acreage at the State level also were expected.

The authors determined the statistical significance of differences in regional/commodity profiles of irrigated acreage between the two time periods by using the multivariate statistical technique profile analysis (7).1/ Profile analysis was designed to test the equality of mean vectors of different groups. Kim and Webb applied profile analysis for testing the statistical significance of structural changes in U.S. agricultural exports (6).

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*Hanchar, Dickason, and Crosswhite are agricultural economists with the Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Barney, formerly with the Resources and Technology Division, is a student at Mary Washington College, Fredericksburg, VA.

1/ Underscored numbers in parentheses refer to sources cited in the References.

BACKGROUND

Farmers adjust output and input levels as producer price-cost relationships change. On the price side, the markets that had contributed to the growth in world demand in the 1970's grew much more slowly or contracted during the 1980's (4). During the early 1980's, U.S. agricultural products became less price competitive in shrinking world markets because of the rising value of the dollar and high U.S. price supports. The supply of U.S. agricultural products exceeded demand.

On the cost side, higher real interest rates and petroleum-related prices raised the cost of producing farm goods in the late 1970's and early 1980's. The more highly mechanized producers and growers who used mechanical pumping of irrigation water, both users of large volumes of energy in the production process, were particularly hard hit by increased real energy prices. Presumably, the reduction in the level of energy and related inputs used by the agricultural sector, especially the irrigated sector, during the period following the second oil price rise was greater than during the first oil price increase when the prices of all goods rose along with petroleum prices.

Another problem increased pumping costs. Some farmland irrigated with ground-water supplies shows chronic ground-water decline (9). These areas include parts of California, Idaho, Arizona, Colorado, New Mexico, Nebraska, Kansas, Oklahoma, Texas, Arkansas, and Florida. As the water table level drops, pumping lifts increase, pushing up pumping costs.

PROFILE ANALYSIS

The authors used profile analysis to determine whether average irrigated acreage for 1976-80, by region and commodity group, equaled average irrigated acreage for the 1981-85 period, by region or commodity group. Profile analysis addresses the equality of profiles in two steps. The hypothetical profiles in figures 1 and 2 help illustrate the concepts. The first step contains a test for a change in the profile. The test pertains to the similarity of the profiles. Profiles are similar if the line segments joining adjacent treatments (in this study, regions or commodity categories) of group one are parallel to corresponding line segments of group two. 2/ Parallel profiles imply that the difference between a treatment mean of group one and the corresponding treatment mean of group two does not vary significantly across treatments. Nonparallel profiles imply that the difference varies significantly across treatments: a change in profile is indicated (fig. 1). If a change in profile has been established, the first step can be repeated for different subsets of the profile to determine which elements are associated with the change in profile.

The authors conduct the second step only if results from step one indicate parallelism, or no significant change in profile. The second step is a test for a profile shift. The test pertains to the coincidence of the profiles. If profiles are at the same level, they are coincident. Assuming parallelism, coincidence implies that the treatment means do not differ between groups.

2/ They are adjacent in a graphical sense only. No other relationship between treatments is suggested. The ordering of the treatments (regions, commodities) is arbitrary and has no effect on the statistical results (7).

Figure 1
Profile change

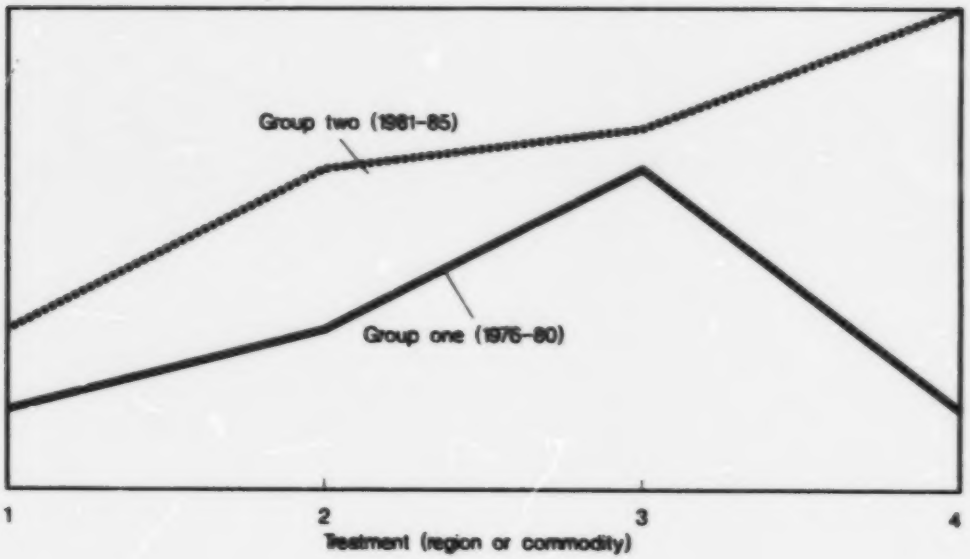
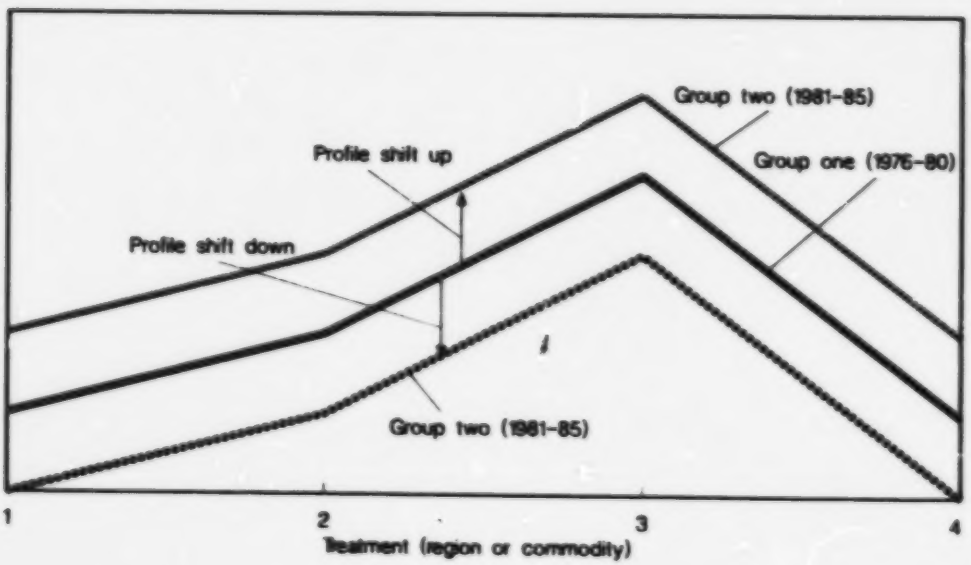


Figure 2
Profile shift up or down



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Again, assuming parallelism, noncoincident profiles imply that the treatment means differ by the same amount between the two groups. Two possibilities exist. The profile of group one can lie above the profile of group two, or the profile of group one can lie below the profile of group two (fig. 2). The situations represented in figure 2 are described as downward and upward profile shifts, respectively.

In profile analysis procedures, the observations, X_{ijk}, are specified as $X_{ijk} = U_{jk} + e_{ijk}$, where X_{ijk} is the ith observation ($i = 1,\ldots,N_j$) of the kth treatment ($k = 1,\ldots,p$) of the jth group ($j = 1,\ldots,m$), U_{jk} is the mean of the kth treatment of the jth group, and e_{ijk} is the residual. For this study, there are either six commodity or six regional treatments (depending upon which aspect is being tested), p=6. To reduce an unwieldy number of regions, the authors formed 10 farm production regions into six groups of neighboring regions: Appalachian and Northeast, Corn Belt and Lake States, Delta States and Southeast, Northern Plains, Southern Plains, and Mountain and Pacific. For a similar reason, we grouped agricultural commodities produced on irrigated cropland into six categories: sugar crops; grains; cotton; oilseeds and legumes; pasture and hay; and fruits, nuts, and vegetables (see table 1 for the commodities in each category). There are two groups of data, m=2. One group represents 1976-80 and the other represents 1981-85. Each group consists of five observations, $N_{j=1}$ and $N_{j=2} = 5$.

The first step, the test for a change in profile, determines whether the two groups' vectors of mean values are parallel and tests the hypothesis of no response by group interaction. The relevant hypothesis to be tested is:

$$H_o : \begin{bmatrix} U_{11} - U_{12} \\ \cdots \\ U_{1,p-1} - U_{1p} \end{bmatrix} = \begin{bmatrix} U_{21} - U_{22} \\ \cdots \\ U_{2,p-1} - U_{2p} \end{bmatrix}$$

Table 1--Crops in commodity categories 1/

Commodity category	Crops in category
Sugar crops	Sugar beets, sugarcane
Grain crops	Barley, corn, mixed grain, oats, popcorn, rice, small grains, sorghum, wheat
Cotton	-
Oilseeds and legumes	Beans, dry beans, peanuts, safflower, soybeans, sunflower
Pasture, hay, silage	Alfalfa, all hay, clover, forage, silage
Fruits, nuts, vegetables	Fruits, tree nuts, and vegetables

1/ Irrigated acreage for all seeds, budding plants, cemeteries, dill, flowers, golf courses, mint, miscellaneous, ornamentals, other sod, tobacco, and turf is not analyzed.

The differences between the U_{jk} measure the slopes of line segments joining adjacent treatments. The hypothesis is rejected if the calculated F value,

$$Fcal = \frac{(N_1+N_2-p)N_1N_2}{(N_1+N_2)(N_1+N_2-2)(p-1)}(\bar{X}_1-\bar{X}_2)'C'(CSC')^{-1}C(\bar{X}_1-\bar{X}_2),$$

exceeds the critical value $F_{\alpha;p-1,\ N1+N2-p}$, where $\bar{X}_j$ is the sample mean vector of the jth group, S is a variance-covariance matrix, and C is a (p-1) by p matrix such that:

$$C = \begin{bmatrix} 1 & -1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & -1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & -1 & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ 0 & 0 & 0 & 0 & \cdots & 1 & -1 \end{bmatrix}$$

If there is no change in profile, the test in the second step determines whether the group series are parallel at the same level or whether one group series lies above or below the other. This is the test for coincidence or a profile shift. Coincident profiles imply that average irrigated acreage, by region or commodity, does not vary significantly between periods. The test hypothesis is:

$$H_o : j'U_1 = j'U_2 ,$$

where j' is a p-component vector with unity in each position, and the alternative hypothesis is either:

$$H_a : j'U_1 < j'U_2, \quad \text{or}$$

$$H_a^* : j'U_1 > j'U_2.$$

The hypothesis is tested by computing:

$$t = j'(\bar{X}_1 - \bar{X}_2) / \sqrt{(j'Sj(1/N_1 + 1/N_2))} .$$

The hypothesis H_o is rejected in favor of H_a if the computed t-value is less than the critical value of $-t_{\alpha;N1+N2-2}$, or in favor of H_a if the computed t-value is greater than the critical value of $t_{\alpha;N1+N2-2}$. A significant negative t-value indicates that the vector of means for group one is less than the vector of means for group two by an amount greater than could be expected by chance alone. A positive t-value indicates that the vector of means for group one is greater than the vector of means for group two. The former indicates an upward shift in profiles between 1976-80 and 1981-85, while the latter indicates a downward shift in profiles.

RESULTS AND INTERPRETATION

U.S. irrigated acreage for 1981-85 averaged about 5 percent more cropland than in 1976-80 (table 2). Irrigated acreage is concentrated in the dry areas of the 17 westernmost contiguous States. The Southeast and Delta States regions accounted for the major share of the irrigated acreage in the 31 easternmost

contiguous States. Although the humid regions of the East made up a relatively small amount of total irrigated acreage, they experienced the largest percentage increases (greater than 27 percent) in average irrigated acreage between 1976-80 and 1981-85. The percentage increases for the Pacific and Mountain as one region, and Northern Plains region were less (less than 9 percent), and a considerable decline of about 16 percent occurred in the Southern Plains region between the two periods. The difference between average irrigated acreage for 1976-80 and 1981-85 varied by region and commodity at the national level and by commodity at the State level. The authors determined the statistical significance of differences in the regional and commodity profiles of irrigated acreage between the two periods by using profile analysis procedures.

Regional Profile of U.S. Irrigated Acreage

Figure 3 shows the regional profiles of U.S. irrigated acreage for the two periods. The profiles reveal that irrigated acreage increased in all regions except the Southern Plains. The hypothesis of parallelism is not rejected in the test for a profile change (table 3). No significant change in profile occurred between the periods. The difference between average irrigated acreage for 1976-80 and the average for 1981-85 did not vary significantly across regions. The line segments joining region means in 1976-80 are relatively parallel to line segments of 1981-85 (fig. 3). The one exception would appear to be the segments joining the Northern Plains and Southern Plains. However, the difference in slope between the profiles is not statistically significant.

DATA

Annual observations of irrigated acreage, by State and commodity, are required to test the hypothesis that the profile of U.S. irrigated acreage remained the same between 1976-80 and 1981-85. Irrigation data are available from several sources: Bureau of Census, U.S. Dept of Commerce (Census of Agriculture, Farm and Ranch Irrigation Survey, Census of Irrigation Organizations); Soil Conservation Service, U.S. Dept. of Agriculture (National Resource Inventory); U.S. Geological Survey, U.S. Dept. of Interior (Estimated Use of Water in the United States); Irrigation Journal (Annual Irrigation Survey). Sloggett provides a detailed description of data sources (8). The Annual Irrigation Survey conducted by the Irrigation Journal is the only source of annual data on irrigated crop acreage for all States. Therefore, data from the Irrigation Journal's Annual Irrigation Survey for 1976-1985 were used in the analysis (5).

At first, the authors planned to include all 50 States in the analysis, but several lacked two or more consecutive years of irrigated acreage data. For this reason, we omitted Alaska, Oregon, Arkansas, Mississippi, Kentucky, Pennsylvania, New Jersey, Vermont, Maine, Connecticut, Rhode Island, and New Hampshire. If an observation was missing for a single year but data for the previous and following years were available, we interpolated a value for the missing year, which was the average of the 2 years' observations.

Table 2—Average irrigated acreage for 1976-80 and 1981-85 for commodity groups, by State and region

State or region	Period 2/	Commodity group 1/						Total 3/
		Sugar crops	Grain crops	Cotton	Oil crops	Pasture, silage	Fruits, nuts, veg.	
		Acres						
Alabama	M1	N/A	30,006	2,480	47,660	1,940	12,552	94,638
	M2	N/A	61,400	4,600	76,200	4,000	12,790	158,990
Arizona	M1	13,300	444,200	561,360	24,700	257,400	134,958	1,435,918
	M2	12,600	281,800	602,040	6,340	224,000	132,976	1,259,756
California	M1	N/A	1,012,600	1,089,600	N/A	2,472,940	3,182,200	7,757,340
	M2	N/A	1,736,200	1,413,800	N/A	1,975,800	3,721,400	8,847,200
Colorado	M1	89,400	1,193,000	N/A	78,400	1,628,400	132,800	3,122,000
	M2	46,200	1,408,200	N/A	111,000	1,066,200	104,000	2,735,600
Delaware	M1	N/A	12,900	N/A	2,180	240	18,540	33,860
	M2	N/A	23,420	N/A	6,400	400	21,340	51,560
Florida	M1	328,000	106,581	N/A	34,771	618,842	968,071	2,056,265
	M2	403,000	177,730	N/A	63,200	429,270	1,098,000	2,111,200
Georgia	M1	N/A	280,140	8,360	267,880	11,900	63,094	631,374
	M2	N/A	343,037	37,161	811,748	15,926	162,533	1,370,405
Hawaii	M1	119,400	N/A	N/A	N/A	N/A	7,800	127,200
	M2	118,800	N/A	N/A	N/A	N/A	15,380	134,180
Idaho	M1	139,440	1,159,340	N/A	182,400	926,700	426,000	2,833,880
	M2	141,260	1,596,860	N/A	166,560	1,398,620	359,020	3,662,320
Illinois	M1	N/A	62,380	N/A	22,200	3,300	8,920	96,800
	M2	N/A	97,660	N/A	41,500	3,700	12,400	155,260
Indiana	M1	N/A	53,814	N/A	6,926	1,880	8,370	70,990
	M2	N/A	89,120	N/A	11,928	3,400	11,150	115,598
Iowa	M1	N/A	146,800	N/A	17,400	N/A	11,800	176,000
	M2	N/A	129,800	N/A	108,200	N/A	12,800	250,800
Louisiana	M1	N/A	605,100	2,500	2,700	13,200	2,820	626,320
	M2	N/A	607,500	2,500	2,800	12,000	2,860	627,660
Kansas	M1	N/A	2,680,380	N/A	113,000	412,000	N/A	3,205,380
	M2	N/A	2,411,420	N/A	244,000	500,000	N/A	3,155,420
Massachusetts	M1	N/A	N/A	N/A	N/A	300	27,200	27,500
	M2	N/A	N/A	N/A	N/A	300	23,840	24,140

See footnotes at end of table.

continued—

Table 2—Average irrigated acreage for 1976-80 and 1981-85 for commodity groups, by State and region—continued

State or region	Period 2/	Commodity group 1/						Total 3/
		Sugar crops	Grain crops	Cotton	Oil crops	Pasture, silage	Fruits, nuts, veg.	
					Acres			
Maryland	M1	N/A	3,867	N/A	3,994	N/A	17,189	25,050
	M2	N/A	12,207	N/A	7,551	N/A	19,942	39,700
Michigan	M1	N/A	128,608	N/A	119,286	7,741	87,982	343,617
	M2	N/A	207,633	N/A	28,689	15,243	98,560	350,125
Minnesota	M1	N/A	295,400	N/A	19,300	16,500	66,600	397,800
	M2	N/A	342,900	N/A	81,400	23,800	50,200	498,300
Missouri	M1	N/A	168,000	10,160	120,500	2,160	854	301,674
	M2	N/A	254,318	12,880	213,480	2,400	3,210	486,288
Montana	M1	47,400	380,700	N/A	10,640	2,312,430	11,150	2,762,320
	M2	43,640	410,380	N/A	12,800	2,685,581	11,870	3,164,271
Nebraska	M1	89,100	5,599,815	N/A	575,600	920,240	27,690	7,212,445
	M2	75,060	5,723,160	N/A	925,380	663,200	8,150	7,394,950
Nevada	M1	N/A	49,200	1,440	N/A	596,000	17,600	664,240
	M2	N/A	34,000	1,300	N/A	423,100	18,000	476,400
New Mexico	M1	N/A	399,020	84,100	10,460	382,800	10,800	887,180
	M2	N/A	400,674	90,420	20,232	395,964	57,776	965,066
New York	M1	N/A	440	N/A	N/A	250	46,640	47,330
	M2	N/A	750	N/A	N/A	200	56,570	57,520
North Carolina	M1	N/A	8,240	270	7,100	5,300	24,680	45,590
	M2	N/A	32,840	823	14,811	4,400	26,594	79,468
North Dakota	M1	10,000	74,486	N/A	18,120	44,400	3,480	150,486
	M2	10,000	113,669	N/A	14,886	67,568	1,323	207,446
Ohio	M1	N/A	6,880	N/A	N/A	4,600	29,600	41,080
	M2	N/A	6,360	N/A	N/A	2,590	25,770	34,720
Oklahoma	M1	N/A	536,594	80,733	90,885	196,169	13,705	918,086
	M2	N/A	438,320	76,560	78,930	186,160	7,106	787,076
South Carolina	M1	N/A	12,563	1,008	6,378	1,333	22,425	43,707
	M2	N/A	47,062	3,368	29,435	3,078	38,761	121,704
South Dakota	M1	N/A	213,920	N/A	14,360	151,400	2,000	386,680
	M2	N/A	267,200	N/A	34,120	158,200	1,240	460,760

See footnotes at end of table.

continued—

Table 2—Average irrigated acreage for 1976-80 and 1981-85 for commodity groups, by State and region—continued

State or region	Period 2/	Commodity group 1/ Sugar crops	Grain crops	Cotton	Oil crops	Pasture, silage	Fruits, nuts, veg.	Total 3/
				Acres				
Tennessee	M1	N/A	1,720	500	N/A	540	10,400	13,160
	M2	N/A	10,360	460	N/A	960	11,940	23,720
Texas	M1	59,880	5,201,320	1,956,000	293,180	472,340	375,320	8,358,040
	M2	61,350	3,546,520	2,254,400	332,260	436,560	334,720	6,965,810
Utah	M1	N/A	449,052	N/A	N/A	905,851	24,569	1,379,472
	M2	N/A	417,685	N/A	N/A	1,113,560	25,513	1,556,758
Virginia	M1	N/A	7,300	N/A	1,880	1,320	16,700	27,200
	M2	N/A	12,600	N/A	5,260	2,120	15,080	35,060
Washington	M1	N/A	516,400	N/A	38,000	543,200	446,500	1,544,100
	M2	N/A	587,800	N/A	50,600	680,000	450,800	1,769,200
Wisconsin	M1	N/A	81,092	N/A	2,224	23,444	74,740	181,500
	M2	N/A	91,440	N/A	2,130	28,855	67,900	190,325
Wyoming	M1	44,560	303,400	N/A	35,200	1,348,322	6,500	1,737,982
	M2	37,320	276,600	N/A	38,400	1,438,570	4,000	1,794,890
West Virginia	M1	N/A	901	N/A	N/A	N/A	730	1,631
	M2	N/A	650	N/A	N/A	N/A	855	1,505
Northeast & Appalachian	M1	N/A	35,368	770	15,154	7,950	162,079	221,321
	M2	N/A	92,827	1,283	34,022	8,380	176,161	312,673
Corn Belt & Lake States	M1	N/A	942,974	10,160	212,407	59,625	288,866	1,514,032
	M2	N/A	1,219,231	12,880	487,327	79,988	281,990	2,081,416
Southeast & Delta States	M1	328,000	1,034,390	36,848	359,389	647,215	1,068,962	3,474,804
	M2	403,000	1,176,729	70,129	983,382	464,274	1,314,944	4,412,458
Pacific & Mountain	M1	453,500	5,906,912	1,736,500	379,900	11,374,043	4,400,877	24,251,732
	M2	399,820	7,150,199	2,107,560	405,932	11,401,395	4,900,735	26,365,641
Northern Plains	M1	99,100	8,573,601	N/A	721,080	1,528,040	33,170	10,954,991
	M2	85,060	8,515,449	N/A	1,218,386	1,388,968	10,713	11,218,576
Southern Plains	M1	59,880	5,737,914	2,036,733	384,065	668,509	389,025	9,276,126
	M2	61,350	3,984,840	2,330,960	411,190	622,720	341,826	7,752,886
Total	M1	940,480	22,231,159	3,821,011	2,071,995	14,285,382	6,342,979	49,693,006
	M2	949,230	22,139,275	4,522,812	3,540,239	13,965,725	7,026,369	52,143,650

N/A = not applicable

1/ For a description of crops in crop categories see table 1.

2/ M1 = 1976-80 and M2 = 1981-85

3/ Totals include only those data presented in the table.

We conducted the test for a profile shift, given that the profiles were parallel. Results show that the regional profiles were not at significantly different levels (table 3). The insignificant t-value associated with the t-test for a profile shift indicates that neither a significantly upward nor downward shift occurred in the regional profile of irrigated acreage between the two time periods. The profiles are coincident. Figure 3 suggests that the profiles were parallel, and that the profile for 1981-85 was generally above the profile of 1976-80. However, average irrigated acreage, by region, in 1981-85 did not differ significantly from the averages in 1976-80.

Figure 3
Average U.S. irrigated acreage, by region, 1976-80 and 1981-85

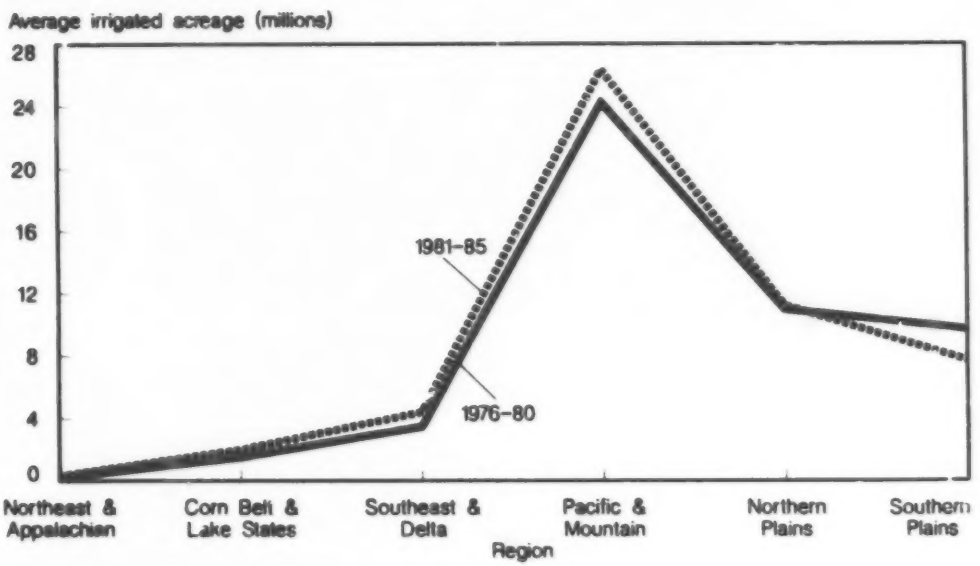

Table 3--Analysis of changes and shifts in regional and commodity profiles of U.S. irrigated acreage, 1976-80 and 1981-85

Type of profile	Test for profile change		Test for profile shift	
	Critical F-value (α =0.05)	Calculated F-value	Critical t-value (α =0.05)	Calculated t-value
Regional	6.26	3.51	-1.86	-1.59
Commodity	6.26	2.96	-1.86	-1.59

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Commodity Profile of U.S. Irrigated Acreage

The commodity profiles of U.S. irrigated acreage for the two periods showed slight decreases in irrigated acreages for grain crop and pasture and hay production (fig. 4). Increases occurred in irrigated acreage for cotton, fruits, nuts, and vegetables, and oilseeds. The hypothesis of parallelism was not rejected in the test for a profile change (table 3). No significant change in profile occurred between the periods. The difference between average irrigated acreage in 1976-80 and the average in 1981-85 did not vary significantly across commodities. Line segments joining commodity means for 1976-80 are relatively parallel to line segments for 1981-85 (fig. 4). Any difference in slope between the profiles was not statistically significant.

Given that the profiles were parallel, the authors conducted the test for a profile shift. The insignificant t-value associated with the test for a profile shift showed that the commodity profiles were at the same level (table 3). Commodity profiles for the two periods were coincident (fig. 4). Average irrigated acreage, by commodity, in 1981-85 was not significantly different from average irrigated acreage in 1976-80.

Commodity Profiles of State Irrigated Acreage

Even thoug changes in the commodity profile of irrigated acreage were not discernible at the national level, some changes may have occurred at the State level. Tests for a change or shift in the commodity profile of irrigated cropland acreage, by State, helped identify adjustments to changing economic conditions in the irrigated agriculture sector. Table 4 contains the results

Figure 4
Average U.S. irrigated acreage, by crop, 1976-80 and 1981-85

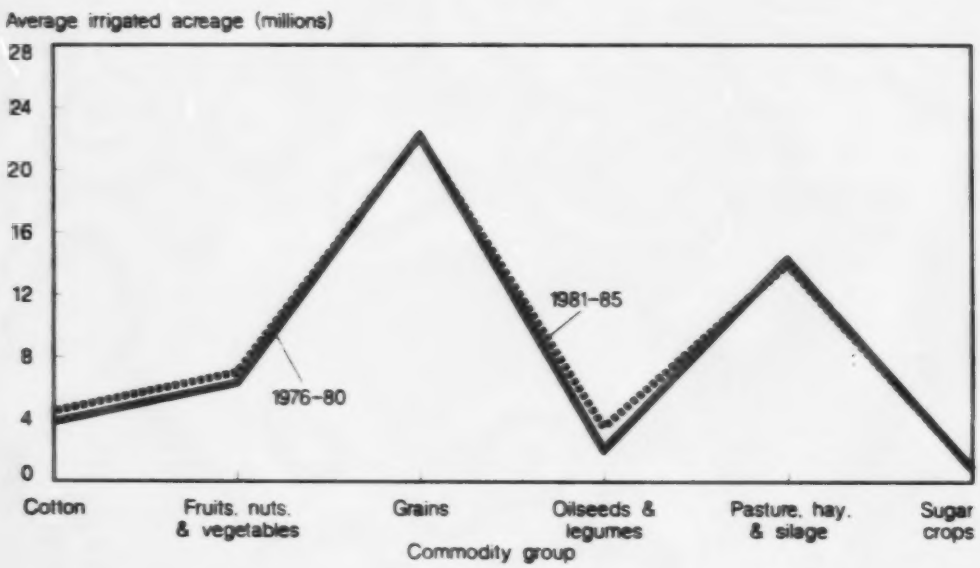

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Table 4—Analysis of changes and shifts in commodity profiles between 1976-80 and 1981-85, by State 1/

State	Commodities in profile 3/						Test for profile change		Test for profile shift 2/	
	S	G	C	O	P	F	Critical F-value (α=0.05)	Calculated F-value	Critical t-value (α=0.05)	Calculated t-value
Alabama		X	X	X	X	X	5.19	11.59		
Arizona	X	X	X	X	X	X	6.26	3.04	1.86	2.31
California		X	X		X	X	4.76	5.53		
Colorado	X	X		X	X	X	5.19	4.21	1.86	1.58
Delaware		X		X	X	X	4.76	3.10	-1.86	-3.65
Florida	X	X		X	X	X	5.19	5.47		
Georgia		X	X	X	X	X	5.19	3.99	-1.86	-2.57
Hawaii	X					X	5.32	2.97	-1.86	-2.36
Idaho	X	X		X	X	X	5.19	3.68	-1.86	-1.86
Illinois		X		X	X	X	4.76	9.91		
Indiana		X		X	X	X	4.76	5.95		
Iowa		X		X		X	4.74	4.47	-1.86	-3.34
Kansas		X		X	X		4.74	16.62		
Massachusetts					X	X	5.32	3.71	1.86	1.93
Maryland		X		X		X	4.74	1.94	-1.86	-2.36
Michigan		X		X	X	X	4.76	4.46	-1.86	- .11
Minnesota		X		X	X	X	4.76	106.62		
Missouri		X	X	X	X	X	5.19	215.13		
Montana	X	X		X	X	X	5.19	8.72		
Nebraska	X	X		X	X	X	5.19	2.59	-1.86	- .54
New Mexico		X	X	X	X	X	5.19	5.40		
New York		X			X	X	4.74	8.88		
North Carolina		X	X	X	X	X	5.19	4.37	-1.86	-3.47
North Dakota	X	X		X	X	X	5.19	29.06		
Ohio		X			X	X	4.74	41.24		
Oklahoma		X	X	X	X	X	5.19	4.61	1.86	3.44
South Carolina		X	X	X	X	X	5.19	9.76		
South Dakota		X		X	X	X	4.76	2.99	-1.86	-2.76
Tennessee		X	X		X	X	4.76	79.81		
Texas	X	X	X	X	X	X	6.26	3.07	1.86	4.43
Utah		X			X	X	4.74	.80	-1.86	- .48
Virginia		X		X	X	X	4.76	2.94	-1.86	-1.59
Washington		X		X	X	X	4.76	2.13	-1.86	-2.43
Wisconsin		X		X	X	X	4.76	.27	-1.86	- .10
Wyoming	X	X		X	X	X	5.19	.55	-1.86	-1.34
West Virginia		X				X	5.32	9.50		

1/ Results for Louisiana and Nevada are not presented because of computational problems arising from little or no variation in the data. In the absence of any statistical evidence, no conclusions are made regarding the significance of differences between the profiles.

2/ The test for profile shift is conducted only if the hypothesis of parallelism in the test for profile change is not rejected.

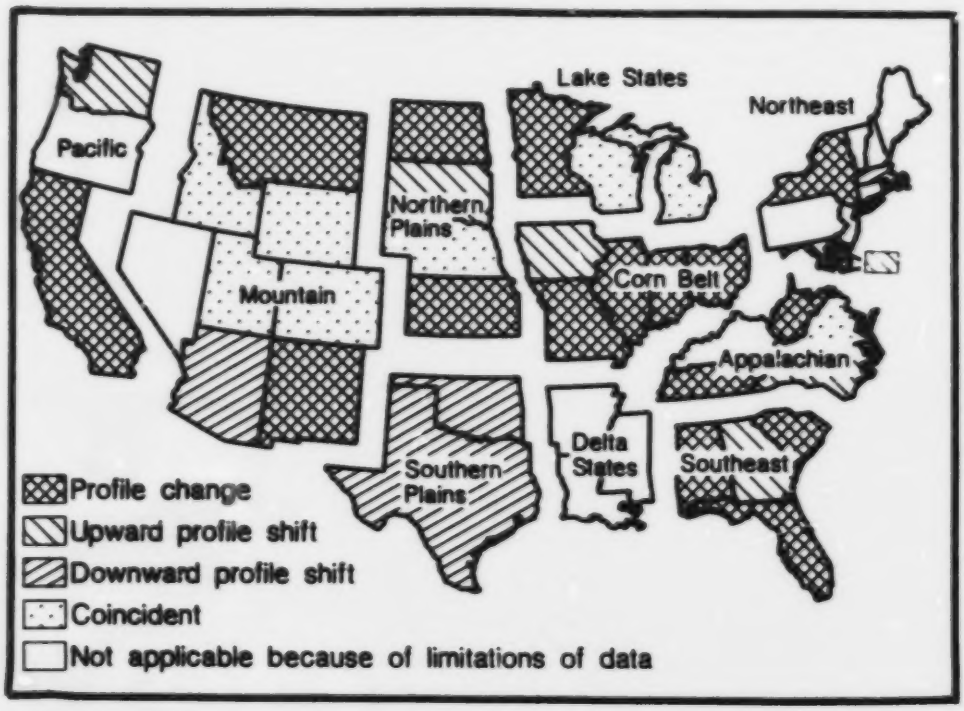
3/ S = sugar crops, G = grains, O = oilseeds and legumes, C = cotton, P = pasture, hay, and silage, F = fruits, tree nuts, and vegetables.

of the tests for changes in the profiles between 1976-80 and 1981-85 for each State and the subsequent tests for profile shifts. Significant changes spanned the commodity profiles of Alabama, California, Florida, Illinois, Indiana, Kansas, Minnesota, Missouri, Montana, New Mexico, New York, North Dakota, Ohio, South Carolina, Tennessee, and West Virginia (fig. 5). Average irrigated acreage differed between the periods, but the magnitude of the change varied across commodities.

Commodity profiles of the remaining States were parallel between the two periods. Delaware, Georgia, Hawaii, Iowa, Maryland, North Carolina, South Dakota, and Washington showed significantly upward shifts in commodity profiles at the 5-percent level. Average irrigated acreage increased between the periods and the magnitude of the increase was constant across commodities. Colorado, Idaho, Michigan, Nebraska, Utah, Virginia, Wisconsin, and Wyoming experienced no significant upward or downward shifts in commodity profiles of irrigated acreage. Average irrigated acreages, by commodity, did not differ between the periods.

In tests for profile shifts at the 5-percent level, only Arizona, Massachusetts, Oklahoma, and Texas experienced statistically significant downward shifts in commodity profiles of irrigated cropland acreage. Average irrigated acreage decreased between the periods, and the magnitude of the decrease was constant across commodities. These results are consistent with the findings of (2) that the arid Southwest reduced irrigated cropland between 1978 and 1982.

Figure 5
Adjustments in commodity profiles of irrigated acreage, by State, 1976-80 and 1981-85



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Analysis of States Experiencing a Profile Change

Rejection of the null hypothesis of parallelism implies an unsystematic change in the commodity profile of irrigated cropland acreage between 1976-80 and 1981-85. The difference between average irrigated acreage of the two periods varied across commodities. To determine which commodity groups were associated with the profile change, the authors conducted a profile analysis on different subsets of irrigated commodity production for each State that experienced a change in the commodity profile of irrigated acreage. Subsets were constructed by omitting one of the commodities in the original profile. Each subset had a different commodity group omitted. Table 5 shows the results of the tests for the hypothesis of parallelism and the subsequent test for profile shifts of various subsets of commodity groups. The authors used the statistical results in table 5 and the changes in irrigated acreage reported in table 2 to further describe the changes in profile that occurred.

The change in the commodity profile of irrigated acreage for Alabama was associated with changes in all commodities between the two time periods. Average irrigated acreage for all commodity groups for 1981-85 was greater than that for 1976-80, but the magnitude of the increase varied across commodity groups. Increases ranged from about 30,000 acres for grains and oil crops to about 200 acres for fruits, nuts, and vegetables.

Average irrigated acreage for grain production in California increased by approximately 700,000 acres between the two periods. The increase contributed to the change in the commodity profile of irrigated acreage in California. No statistically significant change occurred in the commodity profile of irrigated acreage for cotton, pasture, and fruit, nut, and vegetable production between the two periods. The test for a profile shift for the commodity subset was insignificant, indicating little shift in irrigated acreage for cotton, pasture, and fruit, nut, and vegetable production in California between periods.

Irrigated acreage for sugar crop, oil crop, and fruit, nut, and vegetable production in Florida increased by about 75,000, 28,000, and 130,000 acres, respectively, between 1976-80 and 1981-85. Changes in the above crops led to the change in the commodity profile of irrigated acreage in Florida. Profile shifts were statistically insignificant, indicating little shift in irrigated acreage for grain and pasture production in Florida.

Changes in irrigated acreage profiles for Illinois were statistically significant for every commodity subset. Therefore, the change in the commodity profile of irrigated acreage that occurred in Illinois between 1976-80 and 1981-85 was associated with the increases in irrigated acreages across all commodities. Increases in average irrigated acreage for commodity groups ranged from 35,000 acres for grain production to 400 acres for pasture production.

Irrigated acreages for grain, oil crops, pasture, and fruit, nut, and vegetable production in Indiana increased significantly but by different magnitudes between periods. The increase in irrigated acreage for grain crop production was about 35,000 acres, while increases for oil crop, pasture, and fruit, nut, and vegetable production were 5,000 acres or less.

Changes in the commodity profile of Kansas irrigated acreage was traced to a decline in the irrigated acreage for grain production and increases for oil

Table 5—Analyses of subsets of commodity profiles for States experiencing profile change, 1976-80 and 1981-85

State	Commodities in profile 2/						Test for profile change: Critical F-value (α=0.05)	Test for profile change: Calculated F-value	Test for profile shift 1/: Critical t-value (α=0.05)	Test for profile shift 1/: Calculated t-value
	S	G	C	O	P	F				
Alabama		X	X	X	X		4.76	13.88		
		X	X	X		X	4.76	10.38		
		X	X		X	X	4.76	17.87		
		X		X	X	X	4.76	13.76		
			X	X	X	X	4.76	9.06		
California		X	X		X		4.74	9.65		
		X	X			X	4.74	8.82		
		X			X	X	4.74	7.78		
			X		X	X	4.74	4.47	-1.86	-1.06
Florida	X	X		X	X		4.76	2.54	1.86	.52
	X	X		X		X	4.76	7.45		
	X	X			X	X	4.76	1.73	-1.86	- .19
	X			X	X	X	4.76	6.00		
		X		X	X	X	4.76	4.40	1.86	.15
Illinois		X		X	X		4.74	7.35		
		X		X		X	4.74	7.51		
		X			X	X	4.74	8.81		
				X	X	X	4.74	9.16		
Indiana		X		X	X		4.74	9.69		
		X		X		X	4.74	10.11		
		X			X	X	4.74	10.40		
				X	X	X	4.74	8.27		
Kansas		X		X			5.32	29.80		
		X			X		5.32	24.35		
				X	X		5.32	13.63		
Minnesota		X		X	X		4.74	21.98		
		X		X		X	4.74	54.25		
		X			X	X	4.74	112.84		
				X	X	X	4.74	72.86		
Missouri		X	X	X	X		4.76	3.68	-1.86	-3.65
		X	X	X		X	4.76	3.76	-1.86	-3.67
		X	X		X	X	4.76	5.50		
		X		X	X	X	4.76	143.69		
			X	X	X	X	4.76	6.97		

See footnotes at end of table.

continued—

Table 5—Analyses of subsets of commodity profiles for States experiencing profile change, 1976-80 and 1981-85—continued

State	Commodities in profile 2/						Test for profile change		Test for profile shift 1/	
	S	G	C	O	P	F	Critical F-value (α=0.05)	Calculated F-value	Critical t-value (α=0.05)	Calculated t-value
Montana		X		X	X	X	4.76	9.40		
	X	X		X	X		4.76	12.13		
	X	X		X		X	4.76	13.93		
	X	X			X	X	4.76	4.74	-1.86	-1.48
	X			X	X	X	4.76	11.36		
New Mexico		X	X	X	X		4.76	.02	-1.86	- .23
		X	X	X		X	4.76	6.13		
		X		X	X	X	4.76	2.25	-1.86	- .57
			X	X	X	X	4.76	5.03		
New York		X			X		5.32	9.53		
		X				X	5.32	19.25		
					X	X	5.32	19.62		
North Dakota	X	X		X	X		4.76	32.42		
	X	X		X		X	4.76	20.73		
	X	X			X	X	4.76	33.93		
	X			X	X	X	4.76	45.60		
		X		X	X	X	4.76	38.32		
Ohio		X			X		5.32	16.41		
		X				X	5.32	4.93	1.86	1.06
					X	X	5.32	1.03	1.86	1.55
South Carolina		X	X	X	X		4.76	15.59		
		X	X	X		X	4.76	15.11		
		X	X		X	X	4.76	12.20		
		X		X	X	X	4.76	14.06		
			X	X	X	X	4.76	11.89		
Tennessee		X	X		X		4.74	131.20		
		X	X			X	4.74	17.98		
		X			X	X	4.74	24.18		
			X		X	X	4.74	1.74		

1/ The test for profile shift is conducted only if the hypothesis of parallelism in the test for profile change is not rejected.

2/ S = sugar crops, G = grains, O = oilseeds and legumes, C = cotton, P = pasture, hay, and silage, F = fruits, tree nuts, and vegetables.

crop and pasture production. Irrigated acreages for all three commodity groups changed substantially but at different levels between 1976-80 and 1981-85. Irrigated acreage for grain production declined by about 270,000 acres between the two periods, while increases in irrigated acreages for oil crop and pasture production were about 130,000 and 90,000 acres, respectively.

The authors associated Minnesota's changes in the commodity profile of irrigated acreage with increases in irrigated acreage for grains, oil crops, and pasture, and a decline in acreage for fruit, nut, and vegetable production. Irrigated acreage for oil crop production increased by about 62,000 acres. while irrigated acreages for grain and pasture production increased 48,000 and 7,000 acres between periods. Irrigated acreage for fruit, nut, and vegetable production declined by about 16,000 acres.

Changes in irrigated acreages for pasture and fruit, nut, and vegetable production in Missouri contributed to the change in commodity profile of irrigated acreage between 1976-80 and 1981-85. Irrigated acreage for pasture increased slightly, while acreage for fruits, nuts, and vegetables increased by about 2,000 acres between the two periods. Increases in irrigated acreage for pasture and fruits, nuts, and vegetables differed from the increases for grains, cotton, and oil crops which were not significantly different from a statistical standpoint.

Montana showed no significant change or shift in the profile of irrigated acreage for sugar crops, grains, pasture, and fruits, nuts, and vegetables. The authors attributed the change in the commodity profile of irrigated acreage to a change in the irrigated acreage for oil crop production, which increased by about 2,000 acres.

The patterns of irrigated acreage for New Mexico's cotton and fruit, nut, and vegetable production led to the change in the commodity profile of irrigated acreage. Irrigated acreage for cotton and fruit, nut, and vegetable production increased by about 6,000 and 50,000 acres, respectively.

The commodity profile changes in irrigated acreage for New York were associated with increases in the irrigated acreage for grain and pasture production and a decline in irrigated acreage for fruit, nut, and vegetable production. Irrigated acreage for grain and fruit, nut, and vegetable production increased by about 300 and 10,000 acres, and pasture acreage declined slightly between periods.

All commodity groups were associated with the change in the commodity profile of irrigated acreage in North Dakota. The difference between average irrigated acreage for 1976-80 and 1981-85 varied across commodity groups. Irrigated acreage for oil crop and fruit, nut, and vegetable production declined by less than 3,000 acres, and irrigated acreage for sugar crop production remained the same. Irrigated grain and pasture acreage increased by approximately 40,000 and 23,000 acres, respectively.

Ohio's change in the commodity profile of irrigated acreage came from declines in irrigated acreage for grain and pasture production. Irrigated acreage for grain and pasture production declined by about 500 and 2,000 acres and the change in acreage for fruits, nuts, and vegetables was not significant.

The commodity profile of irrigated acreage for South Carolina changed significantly between 1976-80 and 1981-85 because of the increases in irrigated acreage of all commodities. Irrigated acreage for grain, oil crop, and fruit, nut, and vegetable production increased by at least 16,000 acres between the periods, while the increases in irrigated acreage for pasture and cotton production were less than 2,000 acres.

Tennessee's test for profile change in irrigated acreages of cotton, pasture, and fruits, nuts, and vegetables was statistically insignificant. The test for a profile shift was statistically insignificant, indicating no shift in irrigated acreage for cotton, pasture, and fruit, nut, and vegetable production. The change in the commodity profile of irrigated acreage that did occur was the approximately 9,000-acre increase in irrigated acreage for grain production.

Interpretation of State Findings

Analysis at the State level provides detailed information regarding adjustments of the irrigated sector to changing economic conditions. The commodity profile analyses of individual States generated varying results. The States experiencing no change in commodity profile, Arizona, Oklahoma, Texas, and Massachusetts, showed statistically significant downward parallel shifts in irrigated acreages across commodities between 1976-80 and 1981-85. Average irrigated acreage, by commodity, for 1981-85 was significantly less than that of 1976-80, and the magnitude of the decrease was constant across commodities. Less favorable cost-price relationships of irrigated crop production in the States during 1981-85 were associated with reductions in the level of irrigated acreage across commodities. Irrigated agriculture in the Southwestern States of Arizona, Oklahoma, and Texas responded as expected to the less favorable producer cost-price relationships of 1981-85. Increased real energy costs and declining ground-water supplies in the region caused pumping costs to increase. So, farmers converted irrigated production to dryland production which reduces yields. Simultaneous declines in commodity prices and increases in other factor costs amplified the cost-price squeeze and hastened adjustments in cropping patterns.

Although Delaware, Georgia, Hawaii, Iowa, Maryland, North Carolina, South Dakota, and Washington experienced no significant change in commodity profile, the States saw significant upward parallel shifts in the commodity profiles of irrigated acreage. Average irrigated acreage, by commodity, for 1981-85 was significantly greater than that of 1976-80, and the magnitude of the increase was constant across commodity groups. The direction of the change was not expected. All of the States, except Washington, are either humid Eastern States or not usually thought of as principal irrigating States. Much of the growth in irrigation recently has been in humid areas. Crop production in many regions of the West is not feasible without irrigation. Irrigation supplements annual rainfall in the East and reduces the risk of crop failures or smaller output during dry periods. Another eastern advantage is that supplemental irrigation allows crop intensification (for example, increased fertilization, use of higher yielding varieties, increased planting density, and double cropping). The economics of irrigated agriculture in the areas evidently was favorable to sustain the growth in irrigation. The fact that average irrigated acreage, by commodity, for 1981-85 was greater than that of 1976-80 in Washington may be associated with the substantial volume of corn, other feed grains, and soybean exports handled by Pacific ports during the 1980's (3).

Colorado, Idaho, Michigan, Nebraska, Utah, Virginia, Wisconsin, and Wyoming had no significant change or shift in the commodity profile of irrigated acreage. Average irrigated acreage by commodity for 1981-85 was not significantly different from that of 1976-80. Either economic conditions in the States did not warrant a reduction in the level of irrigated acreage, or other reasons existed for the lack of adjustment, especially for Colorado, Idaho, Utah, and Wyoming, Western States that use primarily surface water for irrigation. Long-term contractual agreements, and institutional aspects of water law in the West make the irrigated sector in these areas less responsive to general changes in cost-price relationships. Total use of allocations according to the "use it or lose it" legal philosophy, lack of interest in water conservation, and waste have marked water use for irrigation in areas of the West (1). The stability of irrigated acreage in the Western States between the two time periods is influenced by such factors. Institutional impediments to change in the level of resource use are less evident in Michigan, Nebraska, Virginia, and Wisconsin. The fact that no difference existed in the average level of irrigated acreage between the two periods suggests that the relative cost-price relationships of irrigated crop production were not that different on average.

Significant changes in commodity profiles occurred in: Alabama, California, Florida, Illinois, Indiana, Kansas, Minnesota, Missouri, Montana, New Mexico, New York, North Dakota, Ohio, South Carolina, Tennessee, and West Virginia. Average irrigated acreage, by commodity, differed between the two time periods, but the difference varied across commodities. Average irrigated acreages for all commodity groups in Alabama, Illinois, Indiana, Missouri, and South Carolina were greater in 1981-85 than those in 1976-80. These humid-area States had increased supplemental irrigation during the 1970's and early 1980's. Evidence suggests that cost-price relationships of 1981-85 did little to reverse the trend.

Several principal irrigation States in the West saw change in the commodity profile of irrigated acreage. Average irrigated acreage for grain crop production in California increased between the periods, while acreages for other commodity groups remained the same. Irrigated acreage for oil crops in Montana increased. The changes may be associated with the substantial volume of corn, other feed grains, and soybean exports from Pacific ports during the 1980's (3). The change in the commodity profile of irrigated acreage in Kansas came from a decline in the irrigated acreage for grain production and increases for oil crop and pasture production. Portions of Kansas experienced declining ground-water supplies. Evidence suggests that the cost-price relationships of irrigated grain crop production were less favorable in 1981-85, producing a decline in the level of irrigated cropland for grain crop production. Increases in irrigated acreage for cotton and fruit, nut, and vegetable production caused the change in the commodity profile of irrigated acreage in New Mexico.

Florida, Minnesota, New York, North Dakota, Ohio, Tennessee, and West Virginia also experienced change in the commodity profiles of average irrigated acreage. For the most part, average irrigated acreage by commodity did not decline between 1976-80 and 1981-85.

CONCLUSIONS

Average U.S. irrigated acreage by region for 1981-85 was not significantly different from that of the 1976-80 period. Average irrigated acreage, by commodity group, was not significantly different between the periods. As a whole, the U.S. irrigated sector did not respond as expected to the changing economic environment of 1981-85. The economic environment was generally perceived as being less profitable for farms than that of 1976-80. Yet, relative cost-price relationships in the irrigated sector during 1981-85 were attractive enough on average to keep average irrigated acreage near 1976-80 levels.

Analysis at the national level masked differences existing at the State level. The irrigated agricultural sector in a large majority of States did not experience the expected downward adjustments in the commodity profile of irrigated acreage between 1976-80 and 1981-85. Arizona, Kansas, Oklahoma, and Texas absorbed the greatest effects of statistically significant downward adjustments in average irrigated acreage and less favorable producer cost-price relationships faced by the agricultural sector in general during 1981-85. These four States' problems were exacerbated by declining groundwater supplies and increased pumping costs associated with greater pumping lifts and rising real energy costs.

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UNITED STATES DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
1301 NEW YORK AVENUE, NW.
WASHINGTON, D. C. 20005-4788